would sufficiently represent what goes on in the actual gases with which we have to deal. This expectation, unfortunately, has not yet been fulfilled (see *Proceedings* of the American Philosophical Society, vol. xlii. p. 108). (2) The problem has been treated inductively by arguing upwards from known facts of nature. It is in reference to this second method that the *Times* makes its statement.

So far from its being true, as was supposed by the *Times,* that the argument is based on the assumption that there is no helium in our atmosphere, it is pointed out in the first memoir upon the subject that there must be just such traces of helium and hydrogen in our atmosphere as have since been detected (see *Scientific Transactions* of the Royal Dublin Society, vol. vi. pp. 308 and 309).

The facts of nature which were made the data of the investigation are four in number. The first of these is *that there is either no atmosphere or very little on the moon,* from which it is inferred that the atmosphere which the moon shared with the earth when the two bodies separated, and whatever atmospheric gases have since been evolved upon the moon, have by this time escaped. It can be shown that if this be so, then hydrogen, if uncombined, must be able to escape from the earth. There is, however, but little *free* hydrogen upon the earth, and in the atmosphere there is only the merest trace. If there is in this trace any excess over what returns to the earth in rain or in other ways, this excess is on its way upwards towards the penultimate stratum of the atmosphere, which is the part of the atmosphere from which gases escape. Accordingly, the amount of hydrogen which succeeds in getting away from the earth must be very small, while the store of hydrogen locked up in the ocean and in the solid earth is enormous. It can, moreover, be shown that there is a minute accession of hydrogen to the earth from outside, so that on the whole the quantity of hydrogen upon the earth may be almost stationary.

The second and third facts used as data are that helium and free hydrogen are being continuously supplied from the earth to its atmosphere, and that—probably in both cases, certainly in the case of helium—only a very small percentage of the gross supply is being washed down by rain or in other ways returned to the earth, notwithstanding which *neither the hydrogen nor the helium has gone on accumulating in the atmosphere.* From this it is inferred that the quantity which is present in the atmosphere has adjusted itself to be such that the outflow of these gases from the upper regions of the atmosphere balances the net supply which the atmosphere receives from below.

One other fact in nature is used as a datum—that the earth's potential of gravitation is sufficient to prevent any sensible escape of the lightest of the *abundant* constituents of its atmosphere. This lightest abundant constituent is the vapour of water.

A further paper has been published which is devoted specially to dealing with the behaviour of helium in the earth's atmosphere (see *Astrophysical Journal,* vol. xi. p. 369). In this paper it is shown from the marvellously accurate determinations made by Sir William Ramsay and his assistants that the supply of helium to the atmosphere by hot springs, and presumably the helium which oozes up elsewhere through the soil, is from 3000 to 6000 times more than can be accounted for as being a return to the atmosphere of helium which had been washed down by rain; whereas the argon, oxygen and nitrogen in such springs are all of them present in proportions which are consistent with their having been carried down by rain from the atmosphere. From which it is inferred (1) that nearly the whole of the small quantity of helium in the atmosphere is on its way outwards; (2) that helium would have become a larger constituent of the atmosphere by reason of the influx from below if there had been no simultaneous outflow from above; (3) that the rate of this outflow is presumably equal to the net rate of supply.

The escape of helium from a member of the solar system must be facilitated by the circumstances that those radiations from the sun that can affect helium have the full strength of radiation from the photosphere, inasmuch as the helium in the sun's outer atmosphere emits radiations of the same intensity as the photosphere. This is evidenced by the great helium line D_3 being as bright as the neighbouring part of the spectrum of the photosphere. We have, moreover, to take into account that outpour of corpuscles from the sun which, in the upper regions of our atmosphere, is able to excite into intense activity the internal motions of krypton which produce the green auroral line, and presumably with equal and perhaps increased vigour imparts energy to the molecules of helium which range to still greater altitudes.

G. JOHNSTONE STONEY.

30 Ledbury Road, W., January 7.

On the Origin of Spiral Nebulas.

THE ever increasing interest and importance of studies relating to celestial phenomena naturally lead up to questions which, in the present state of our knowledge, can (from the purely theoretical standpoint) in some cases be answered in a fairly satisfactory way.

The object of this note is to present certain views (some of which are believed to be new) on the probable origin of spiral nebulas, having given to start with an incandescent body like our sun.

From theory and observation we know that when different parts of the same fluid body have largely different temperatures the mass is in unstable equilibrium. The constant tendency of the resulting flow of the fluid is to equalise the temperature throughout the mass.

If the maximum temperature is in the interior of the body and the outside is exposed to a much lower temperature, the flow near the surface, through a gradual congealing of the latter, will be retarded. Such a surface will then also act as an insulator and shield to prevent both the too rapid loss of internal heat and the free escape of the accompanying gases.

The visible photosphere of the sun is known to be in a highly heated condition, and the fact that it is almost constantly being ruptured (in some zones more strongly and frequently than in others) shows—reasoning from analogy—that the solar surface has the properties of a fluid in such a state of unstable equilibrium that the superheated confined masses in the interior are still able to break through this surface at many points.

If the sun did not rotate on an axis, this surface would probably be of uniform strength throughout, for the interior circulation would then be radial. The resultant, however, of the rotary and radial forces acting on each particle produces not only an ellipsoidal figure, but also has the tendency to cause each ascending particle to move towards the equator.

As a result there is a tendency to produce surface-flow towards the equator causing an accumulation of cooled matter along the zone which but for this flow would be the weakest part of the whole rotating surface. It is therefore to be expected that two zones of least strength should exist in the solar surface, symmetrically situated with reference to the equator, but at some distance from it.

Now what is most likely to happen after a body like the sun has contracted to such a radius that the surface exists in the plastic or semi-solid state?

Such a surface will act as an insulator producing a more nearly uniform internal temperature and a consequent decrease in the interior circulation. The surface flow having ceased, and the axial velocity of rotation having increased, the zone of least surface-strength will coincide with the equator.

During the time required to reach this stage of the body's history it is probable that the lesser vents were gradually closed as the surface became stronger, resulting in periodic outbursts of increasing magnitude at a smaller number of openings until finally these also were closed.

As the *weight* of each particle of matter in the surface has increased inversely as the square of the radius (the sun's radius being unity), the internal pressure has been increased. Through the continued contraction of the outer surface this pressure, no longer relieved by periodic outbursts, increases far beyond the limit necessary to support the surface; as a result, the outer boundary grows hotter and consequently weaker, so that at last a great rupture of the surface takes place on or near the equator.

The moment this break occurs, the interior masses and

gases, which under great pressure have the properties of a fluid, move with various velocities, and along more or less curved lines toward the opening.

That component of the resulting momentum which acts at right angles to a diameter through the point of rupture causes an excess of pressure along this diameter; this excess, in the nature of a reaction, acting on a surface already strained to near the breaking point, finally causes a second rupture at the diametrically opposite part of the body.

The ejected masses will not all have the same velocity; those parts near the outer boundary of each stream will be deviated and retarded through side currents and friction at the aperture; the central parts of the stream will, in general, acquire the highest velocity, sufficient to carry the lighter matter in a radial direction far beyond the sphere of sensible attraction of the parent mass, where it finally attains a uniform velocity. The heavier masses and those near the borders of the opening will form secondary streams having various inclinations and velocities which, if there were no rotation, would be incomplete arcs of hyperbolas, parabolas and ellipses, in all of which the lighter masses would continually be outstripping the heavier ones.

Through the rotation, however, the outer parts of every stream are left behind the parts nearer the origin, so that each stream falls into a spiral curve of a more or less complicated form, resulting in an increase in the confusion of detail with diminishing distance from the centre.

If the orifices are on the equator, the radially ejected streams will be plain spirals. If the line joining the two orifices is inclined to the equator the streams will be of double curvature, each producing a spiral in the form of a helix[1] (conical). This class of nebulas not being confined to a single plane will, as a rule, exhibit much confusion of detail in projection.

In general a practically straight line drawn from the origin to any part of the plane spiral represents the actual path traversed by the matter in that particular part of the spiral, and the angular length of any given mass, measured in the direction of increasing distance from the origin, represents the corresponding arc through which the parent body rotated, in the opposite direction, while this particular mass was being cast out.

The two principal factors which operate to produce the observed form of any particular spiral are:—(1) internal pressure; (2) velocity of axial rotation.

The decrease in pressure, after the surface has been ruptured, may in some cases be so rapid that the orifices close up before the body has completed a single rotation; such a body will, later on, repeat the process, the orifices remaining open for a longer period; later still the surface will have reached such a condition that the orifices remain open for an indefinite period, finally reaching a stage represented (on a small scale) by the earth's present condition.[2]

If the earlier conditions were such that at the time of the first great eruption long ages were required for a single rotation of the body, the observed form indicates that the internal pressure remained nearly constant, and that the angular velocity was continually being accelerated. (Owing to the removal of heated matter from the interior the contraction was much more rapid than that which would have resulted from simple loss of heat at the surface.)

According to this theory, then, the spiral nebulas reveal to us the past history of the forces operating at the mouths of the two opposing volcanoes.[3] The fluctuations in the forces and in the relative amount of matter belched forth simultaneously by each crater are faithfully recorded in the often twisted, broken, serrated and irregular aspect of the masses which make up the general outline of the main hyperbolic spiral curves. This history covers the period from the first great catastrophe, represented by a distant large mass at the extreme outer limit of one branch, telling us which of the two orifices was the first to relieve the internal pressure, down to the time when the outer portions of the numerous inner streams having less initial velocity but the same angular length—or perhaps the outer portions of the main streams of a later eruption—reached to such distances from the centre as to produce too much confusion of detail for further trustworthy analysis of the form seen in projection.[1]

The generally more dense and more luminous inner boundary of the main spiral curves plainly indicates that after all these ages the lighter more swiftly moving but later ejected particles are still bombarding the earlier slower moving masses. Every time either orifice came nearly in line with, say, a particular distant previously ejected mass, the more swiftly moving particles were sent on their invisible course, many on the way transferring part of their energy of motion to other particles and to the production of the accompanying phenomena of heat and light; others to find free passage, leaving far behind those masses ejected in the same direction at previous rotations (thus crossing in radial directions the space between the main spiral arcs), finally to overtake, some to bombard the particular mass, thus helping to keep it luminous, others, like all parts of the main spiral, to continue their outward journey indefinitely, or until some other obstruction changes their energy of mass-motion into a different equivalent. Through the action of gravity the particles ejected by one body—aided by those coming from other sources—play their part to re-create the conditions leading to a repetition of the parental experiences.[2]

Isolated or heavier condensations on the spiral arcs will generally take on a cometary form indicating the direction from which the particles come. I would suggest that a long nebulous mass, as, for instance, H.V. 14 Cygni, may be a part of some great spiral (perhaps approaching and relatively near to the earth); if this is so, the general direction of the parent mass is plainly indicated in the visible structure of this nebula

When the eruptions are periodic and of very short duration, the heavy surface-matter ejected at each re-opening of the craters will not be carried beyond the limits of the system. Certain results I have recently obtained seem to show that the masses forming star-clusters are the innermost parts of spiral structures similar to those considered in the present paper.

In the case of the great cluster in Hercules, the star-like masses are found to be connected by *nebulous streams which first leave then return towards the centre of the cluster*, showing that the initial velocity of ejection was insufficient to carry these masses (which can hardly be called stars in the ordinary meaning of the word) beyond the sphere of central attraction. A similar arrangement is found to exist among the stars near γ Cassiopeiæ. The two known nebulas near this star (first photographed by Barnard and Wolff) are but the more condensed parts of a broad spiral-like nebulous band (made up of similar condensations) which can be traced from near the middle of the second quadrant up to within a few minutes of arc of the naked eye star in the fourth quadrant. More complete details have been sent to the *Astronomical Journal* for publication.

In conclusion, it may be permitted once more to direct attention to a unique case in solar observation, bearing, as it does, directly upon the subject of the origin of spiral nebulas. How much, or rather how little, importance has been attached to this particular phenomenon, and to the "mechanical theory of comets"[3] put forward at the time,

[1] Photographs of these objects can be found in various astronomical publications. The most complete work in this line has been done by Isaac Roberts, D.Sc., F.R.S. See his "Photographs of Stars, Star Clusters and Nebulæ," vols. i. and ii.

[2] It is worthy of notice, in this connection, that the two most disturbed terrestrial regions are diametrically opposite to each other and near the equator. The deep-seated character of these disturbances is shown quite conclusively by the observed phenomena. Martinique belongs to one region, Krakatoa to the other.

[3] Spectroscopic and photometric changes in the light of certain fixed stars, when considered in connection with the phenomena which would be produced by two radially moving columns of matter (incandescent at the orifices and rotating about a fixed axis inclined at a given angle to the line of sight), might in some cases lead to more satisfactory explanations of the observed data.

[1] Through irregular variations in the pressure at the orifices, and through differences in the amount of matter ejected at different times, an endless variety of forms can be produced.

[2] Readers acquainted with Lockyer's views will notice that I adopt the theory of the meteoric constitution of nebulous matter. The evidences in favour of this theory are fully set forth in the work entitled "The Meteoritic Hypothesis," by Sir Norman Lockyer, K.C.B., F.R.S.

[3] See "Contributions from the Lick Observatory," No. 4, p. 118 *et seq.* This theory calls for just such crucial, seemingly abnormal but really typical phenomena as were presented by Borrelly's last comet.

is voiced in the language of one of the ablest descriptive writers on astronomical subjects of the present day. On p. 127 of her late admirable work entitled "Problems in Astrophysics," Miss Clerke dismisses the subject with the words, "*The only genuine 'eclipse comet' so far captured was that seen and photographed at Sohag 17th May,* 1882." This talented writer makes not the slightest reference to the fact that the 1893 phenomenon differed in one important particular from all those it is said to resemble—that it possessed the one *observed* element which even the genuine object does not lay claim to, namely, the photographs prove that this object *moved,* receded from the sun through an angular distance equal to two-thirds of the solar diameter in less than four hours.[1] On the Mina Broncis photographs this object is plainly connected with the sun by a single, straight, isolated coronal stream.[2] J. M. SCHAEBERLE.

Ann Arbor, December 19, 1903.

Dynamical and Granular Media.

I SHOULD be very much obliged if any reader of NATURE who has studied the matter could enlighten me on the following point.

We may regard a *dynamical system* as commonly understood as being a system which, when left to itself, obeys the Hamiltonian equations

$$\frac{dx}{dt}=\frac{\partial U}{\partial \xi}, \text{ \&c.,} \quad \frac{\partial \xi}{\partial t}=-\frac{\partial U}{\partial x},$$

where $x, y, \ldots$ are generalised coordinates, $\xi, \eta, \ldots$ generalised momenta, and

$$U=\tfrac{1}{2}(\xi\xi)\xi^2+(\xi\eta)\xi\eta+ \ldots +V \quad \ldots \ldots (1)$$

and V, $(\xi\xi)$, $(\xi\eta)$, &c., are any functions whatever of $x, y, \ldots$

We may regard a *granular medium* as a particular kind of system coming under this heading for which U takes the form

$$U=\Sigma_r\frac{\xi_r{}^2+\eta_r{}^2+\zeta_r{}^2}{2m_r}+\Sigma\Sigma_{rs}F_{rs}\{[(x_r-x_s)^2+(y_r-y_s)^2+(z_r-z_s)^2]^{\frac{1}{2}}\} \quad (2)$$

where m_r stands for any constant (being the mass of the rth particle, atom, corpuscle, grain, or whatever else you like to call it) and F_{rs} is any function whatever, continuous or discontinuous, determined by the law of force between different masses.

What I want to know is this:—

(1) Is every dynamical system which can exist in Euclidean three-dimensional space transformable into a granular system according to the above definition by a proper choice of coordinates?

(2) If not, what are the precise mathematical conditions under which a dynamical system can be so transformed?

We may put these questions in a somewhat different form. It is undoubtedly possible to conceive a universe the physical phenomena of which are represented by equations of any assumed form whatever, and therefore not necessarily by the equations of dynamics. Is it possible to conceive a universe the physical phenomena of which *are* represented by dynamical equations, but cannot be accounted for by means of a granular medium? I have read many treatises and essays dealing with theories of the ether, in which it has been tacitly assumed that the only possible answer to (1) must inevitably be "yes," and I cannot but feel that a discussion in your columns might be of much use to physicists.

G. H. BRYAN.

Phosphorescence of Photographic Plates.

I OBTAINED the following results, which are new to me, in the course of some experiments on the action of light on the salts of silver.

I have not yet thoroughly examined the light or radiation emitted in these experiments, but its actinic power is low, and it appears to render the brush discharge from an induction coil more luminous.

The sensitive silver salts, such as the bromide, iodide and chloride, if precipitated and kept in the dark, have the property, under certain conditions, of emitting light in degrees proportionate to their sensitiveness. Thus the bromide, which is the most sensitive, emits more light than the iodide and chloride. A convenient way of observing the phenomenon is to take a bromide photographic plate and place it at once (*without* having exposed it) in ordinary pyro soda developing solution and allow it to remain for ten minutes. Take out of the solution, wash, extinguish the "red lamp," and in total darkness plunge it suddenly into a dish containing a saturated solution of aluminium sulphate. The plate immediately becomes phosphorescent, and the solution also is luminous, but not so bright as the plate is at first. The light gradually weakens, and in a minute or two dies away. On pouring the solution off the plate into a bottle, the whole body of the liquid becomes luminous, and has the appearance of "bottled moonlight." It remains so several minutes, and the light is increased by shaking the liquid.

If half the plate be exposed to the action of white light for a second before treating with the pyro soda solution, that half remains dark and emits no light when the plate is put into the aluminium sulphate. If the plate is given a short exposure in the camera, and developed and put into the aluminium sulphate solution, the image will appear dark on a phosphorescent background.

On placing some precipitated bromide of silver (which had been kept a few days in a corked test-tube in the dark) in a porcelain dish and exposing it to a bright red light whilst adding the pyro-soda solution, it appears black, but on pouring off the solution the precipitate gradually assumes a bright green appearance under the red light, whilst in white light it appears dark grey or black.

The remarkable part of these experiments appears to me to be the fact that the exposing of the silver salts to the action of light destroys their power of emitting it under the treatment described, whilst the salt precipitated and treated in total darkness emits light freely.

T. A. VAUGHTON.

Ley Hill House, Sutton Coldfield.

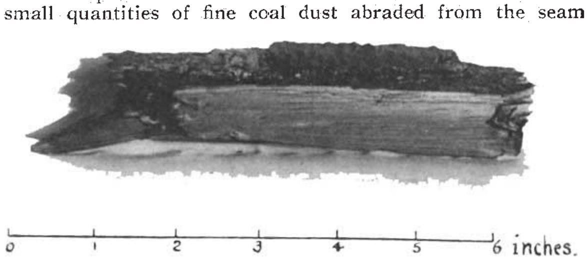
Formation of Coal

SOME of your readers will no doubt be interested to see the photograph sent herewith, which represents a peculiar growth of coal on a piece of timber.

The timber is part of a wooden trough into which, for a period of three years, water had been delivered by tanks lifting the water from a coal-mine shaft.

The formation of coal was found adhering to the vertical sides of the trough, forming a miniature coal seam about a quarter of an inch thick. This coal is hard and bright, and its texture and solidity differ in no respect from ordinary coal.

The explanation seems to be that the water contained small quantities of fine coal dust abraded from the seam



below, and these, either through the motion of the water or by some other means, were filtered out and formed anew into solid coal.

I believe this phenomenon has never previously been observed, and it appears to show that a coal seam may be broken up, washed away, and again built up in a new position without the aid of either the passage of time, pressure or heat. HENRY HALL.

Rainhill, January 3.

The Lamprey.

I SHALL feel obliged to any of your readers who will kindly tell me where to procure specimens of the lamprey. They are unobtainable at the Marine Stations of Millport and Plymouth. J. PENTLAND-SMITH.

St. Regulus, Park Place, Elie, N.B., January 5.

[1] See *Astronomical Journal*, No. 318. Also Mr. Wesley's article in *Observatory*, No. 220, p. 349.
[2] See rough sketch in "Astronomy and Astrophysics," 1894, p. 307.